PATENT SPECIFICATION

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(54) METHOD AND ASSEMBLY FOR USE IN MAKING POWDER METALLURGY ARTICLES HAVING INTERNAL PASSAGES

(71) We, CRUCIBLE INC., a Corporation organised and existing under the laws of the State of Delaware, United States of America, of P.O. Box 88, Parkway West and Route 60, Pittsburgh, State of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The invention relates to compacted alloy articles and the methods of production thereof.

It is customary to produce molds and dies for uses such as plastic injection molding from highly alloyed steels and superalloys, such as nickel- and cobalt-base alloys. Broadly, the conventional procedure is to produce a wooden model or pattern of the desired finished part. From this pattern replicas are produced for use in rough machining blocks of the desired alloy by die sinking. After rough machining the product is subjected to further finish machining to the desired mold or die configuration. In many applications of this type it is necessary to provide the mold or die with internal passages for circulating a coolant adjacent the mold or die surface. Because the cooling passages must generally be exact and somewhat intricate in configuration, this adds further to the already expensive machining operations incident to producing molds and dies.

It is accordingly the primary object of the present invention to provide a method for producing compacted alloy articles having internal passages, and particularly molds and dies having internal cooling passages, without requiring extensive machining operations, thereby greatly decreasing the production costs. Assemblies which may be used in the practice of the method of the invention are also provided. According to the invention there is provided a method for making a compacted alloy article having an internal passage, which comprises placing an alloy particle charge from which said article is to be constructed adjacent the surface of a ceramic core having a surface corresponding to the desired configuration of a surface of the article, placing a ceramic insert having a configuration corresponding to the configuration of an internal passage desired in the article to be produced within said alloy particle charge at a location and orientation spaced from said surface of said ceramic core, and heating said alloy particle charge to an elevated temperature sufficient for compacting, isostatically compacting said alloy particle charge against said surface of said ceramic core and about said ceramic insert without substantially deforming said insert to form a compacted article, removing said ceramic core from said compacted article to expose thereon said article surface, and removing said ceramic insert from said compact to produce therein the internal passage.

There is also provided an assembly comprising a mold corresponding generally to a desired exterior surface of said compacted article, said mold having therein a ceramic core having a surface with a configuration corresponding to the configuration desired on a surface of said compacted article, an alloy particle charge of an alloy composition from which said compacted article is to be constructed positioned within said mold and adjacent said surface of said ceramic core, a ceramic insert having a configuration corresponding to the configuration of the internal passage desired in said compacted article positioned within said alloy particle charge at a location and orientation spaced relative to said ceramic core surface corresponding to the desired location and orientation of said internal passage within said compacted article, and a sealable container having a finely divided solid pressure medium therein

surrounding said mold, said mold being positioned within said container.

Reference is now made to the accompanying drawings, in which:

Figures 1A and 1B are plan and side elevation views, respectively, of an embodiment of a ceramic core for use in the practice of the invention;

Figure 2 is a schematic showing of a container with a core and ceramic insert therein for use in producing molds in accordance with the invention;

Figure 3 is a vertical section taken along lines III—III of the container shown in Fig. 2;

Figure 4A is a photograph showing the cavity of a mold produced by the use of the core shown in Figs. 1A and 1B;

Figure 4B is a photograph of the mold of Fig. 4A with a portion cut away to show the cooling passage therein and adjacent the mold cavity;

Figure 5 is a schematic showing of an assembly for use in an alternate embodiment of the method of the invention.

Broadly, in the practice of the invention compacted alloy articles having internal passages, such as molds and dies having internal cooling passages, are produced by providing a core of ceramic material that is shaped to the configuration desired on a surface of the article, such as for example, a mold cavity. Also, a ceramic insert having a configuration corresponding to that desired in the internal passage of the article is provided. It is to be understood, of course, that the invention may be used to provide an article having an internal passage in applications not requiring forming of a particular exterior surface. Although various ceramics may be used, it is preferred that the ceramic material be characterized by the ability to resist significant size change or deformation upon compressive loading at elevated temperatures incident to hot isostatic compacting. High alumina- or zircon-type ceramics are preferred, specifically 95% alumina or zircon with silica as a binder e.g. collodial silica. A ceramic core of a configuration of, for example, that desired in a mold cavity is placed in a container wherein the surface of the core with the configuration desired in the mold cavity is placed adjacent a charge of alloy particles of a composition from which the mold is to be constructed.

A ceramic insert is positioned within the alloy particle charge at a location relative to the core surface corresponding to the desired relative position of the internal passage in the final compacted article. After evacuating the container to remove any moisture present therein, the container is sealed against the atmosphere and the charge is heated to compacting temperature within the range of 1800° to 2300°F. While at this temperature the container and charge are compacted by the use of isostatic pressure which is achieved by placing the container within a fluid pressure vessel, commonly termed an autoclave, of the well-known type that achieves compacting by the use of gas or other fluid pressure media. Although one-step compacting is preferred, obviously in accordance with well-known practice a precompacting step or steps may be used if desired. In any event, however, compacting is achieved to provide final densities approaching 100% of theoretical and in any event of at least about 98%. After compacting is completed the ceramic core and ceramic insert are removed from the compacted charge. Removal of the ceramic core exposes the adjacent compacted surface of the compacted charge which is of a configuration corresponding to that of the core and desired, for example, for the mold cavity. Like-wise, removal of the ceramic insert produces an internal passage of a configuration corresponding to that of the ceramic insert and located and oriented relative to the mold cavity in accordance with the positioning of the insert within the particle charge relative to the core surface prior to compacting.

With respect to the drawings and at present to Figures 1A, 1B, 2 and 3 thereof, there is shown in Figs. 1A and 1B a non-deformable ceramic core 10. The core 10 is of a configuration corresponding to that desired of a mold cavity. Two of the cores 10 are placed in a cylindrical mild-steel container 12, as shown in Figs. 2 and 3, and alloy powder 14 is packed around the cores 10 and fills the container. A thin sheet of mild steel, indicated in Fig. 2 as 16, is positioned, as shown in the Figures, separating the cores 10. The sheet 16 is preferred for use in this embodiment of the practice of the invention to indicate the position of the cores within the container to facilitate removal and separation after compacting is completed. Adjacent each of the cores 10 there is provided a nondeformable ceramic insert 18 positioned longitudinally relative to the container and embedded in the alloy powder 14. Although only a single insert is shown relative to each core 10 it is understood that a plurality of inserts could be used depending on the nature of the internal passages desired in the final article, and the inserts may be either connected or spaced apart depending upon whether connecting passages are desired. If desired the ceramic inserts 18 may be connected to the wall of container 12 to facilitate maintaining them in fixed position during filling of the container with the particle charge 14. In any event, however, the inserts 18 are positioned and oriented in the particle charge relative

to the core 10 in accordance with the relative position of the internal passage desired in the final compacted article.

The assembly as shown in Figs. 2 and 3 is evacuated to remove any moisture from the interior of the container, and the container is sealed against the atmosphere. The assembly is then placed in an oven (not shown) and heated to compacting temperature, at which time it is placed in a fluid pressure vessel whereupon by the application of fluid pressure the charge is compacted to a density approaching 100% of theoretical. In accordance with conventional autoclave practice the pressure medium employed may be nitrogen gas. After compacting and cooling of the assembly, the assembly is separated at the divider 16 and the ceramic cores are removed to expose two separate compacts having surfaces corresponding to the core configurations. These surfaces constitute the desired mold cavities. By cropping the compacts transversely at a location corresponding to the ends of the ceramic inserts 18, the inserts are exposed for removal to produce an internal passage in the compacted alloy article corresponding in configuration, location and orientation to configuration, location and orientation of the ceramic insert in the particle charge prior to compacting. Likewise, in most instances, the container 12 would be removed from the compacts. The photograph of Fig. 4A shows the mold cavity of the mold produced by the above-described compacting operation. The photograph of Fig. 4B shows the back of the mold cut away to expose the internal passage created upon removal of the ceramic insert 18.

The mold shown in Figs. 4A and 4B and produced as above-described is of a conventional IN—100 alloy composition. The ceramic cores used were of 95% alumina, 5% silica with the silica employed as a binder. The cores were produced by forming a "green" compact from an admixture of particles of alumina and silica, which compact was then fired at elevated temperature to sinter and densify it. The alloy particle charge of the IN—100 alloy was of a size consisting of minus 80 mesh U.S. Standard. As may be seen from the photographs of Figs. 4A and 4B little or no machining is required of the as-compacted article.

An additional embodiment of the invention is shown in Fig. 5 of the drawings. In this embodiment an arrangement of ceramic cores 10, divider 16 and ceramic inserts 18 are positioned within the alloy particle charge 14 in accordance with the practice described in relation to Figs. 2 and 3, except that the container in the embodiment of Fig. 5 is a mold 40 with the mold corresponding generally to the desired exterior surface configuration of the compacted article. The mold may be of any suitable material with the ceramic materials silica, zirconia, alumina or mixtures thereof being preferred. The mold 40 as shown in Fig. 5 is placed within a container 42 which, for example, may be constructed from mild, carbon steel. The container 42 has a stem 44. The container is filled with a finely divided solid secondary pressure medium 46 which may be silica or alumina in finely divided form. This secondary pressure media 46 preferably completely fills the container 42 and surrounds the mold 40. With the assembly constructed as shown in Fig. 5 of the drawings the interior thereof is outgassed in the well-known conventional manner. This requires the connection of the chamber interior *via* stem 44 to a suitable vacuum pump (not shown) to, in the conventional manner, removes gaseous reaction products produced therein during heating. For this purpose heating to a relatively low temperature of about 400 to 500°F. is generally satisfactory. After outgassing, the stem 44 is closed to seal the interior against the atmosphere. The entire assembly of Fig. 5 is transferred to a heating means such as a furnace which heats the assembly and particularly the alloy particle charge 14 to a suitable compacting temperature. The assembly is then placed in an autoclave and unitarily compacted by the application of isostatic pressure in the well-known manner to compact the particle charge 14 to high density. Upon removal of the mold from the container, and after removal of the ceramic cores 10, inserts 18, and mold 40 from the exterior of the compact, two alloy compacted molds are produced, of the type described with reference to Fig. 2 and 3, except that the exterior surface is shaped in accordance with the configuration of mold 40. In this manner molds may be produced that are in the as-compacted state suitable for use with specific backing-structure designs. Therefore, with this embodiment of the invention, not only are the mold cavity and internal cooling passages produced in an as-compacted article but the remaining exterior surfaces of the molds may be likewise of any desired size and configuration depending upon a specific end use.

WHAT WE CLAIM IS:—

1. A method for making a compacted alloy article having an internal passage, which comprises placing an alloy particle charge from which said article is to be constructed adjacent the surface of a ceramic core have a surface corresponding to the desired configuration of a surface of the article, placing a ceramic insert having a

configuration corresponding to the configuration of an internal passage desired in the article to be produced within said alloy particle charge at a location and orientation spaced from said surface of said ceramic core, and heating said alloy particle charge to an elevated temperature sufficient for compacting, isostatically compacting said alloy particle charge against said surface of said ceramic core and about against said ceramic insert without substantially deforming said insert to form a compacted article, removing said ceramic core from said compacted article to expose thereon said article surface, and removing said ceramic insert from said compact to produce therein the internal passage.

2. A method according to claim 1, wherein the ceramic core and the ceramic insert are each constructed from an admixture comprising zircon or alumina, and silica as a binding agent.

3. A method according to claim 2, wherein the binding agent is colloidal silica.

4. A method according to any one of the preceding claims, wherein the alloy particle charge is compacted while at a temperature within the range of 1800 to 2300°F.

5. A method according to any one of the preceding claims, wherein said alloy particle charge is compacted to a density of at least 98% of theoretical.

6. A method according to any one of the preceding claims, wherein said alloy particle charge, ceramic core and ceramic insert are within a sealed container, said sealed container being subjected to fluid pressure during compacting.

7. A method according to claim 6, wherein the container, with said particle charge, ceramic core and ceramic insert therein, is evacuated prior to sealing and compacting.

8. A method according to claims 1—5, which comprises forming an assembly by placing said alloy particle charge having said insert and said core therein in a mold corresponding generally to a desired exterior surface of the article to be produced, placing said mold in a container having a finely divided solid secondary pressure medium therein, evacuating said container and sealing the container, the resulting assembly being subjected to the isostatic compacting at the elevated temperature by application of fluid pressure to said assembly, and removing said mold from the container prior to removing the ceramic core and insert.

9. A method according to claim 8, wherein the mold is constructed from a material comprising zirconia, alumina or a mixture thereof.

10. A method according to any one of the preceding claims, in which the article produced is a mold or die, said internal passage being adapted for coolant circulation within said mold or die.

11. An assembly for use in making a compacted alloy article, said assembly comprising a mold corresponding generally to a desired exterior surface of said compacted article, said mold having therein a ceramic core having a surface with a configuration corresponding to the configuration desired on a surface of said compacted article, an alloy particle charge of an alloy composition from which said compacted article is to be constructed positioned within said mold and adjacent said surface of said ceramic core, a ceramic insert having a configuration corresponding to the configuration of the internal passage desired in said compacted article positioned within said alloy particle charge at a location and orientation spaced relative to said ceramic core surface corresponding to the desired location and orientation of said internal passage within said compacted article, and a sealable container having a finely divided solid pressure medium therein surrounding said mold, said mold being positioned within said container.

12. An assembly according to claim 11, wherein the mold is constructed from zirconia, alumina or a mixture thereof.

13. A method for making a compacted alloy article according to claim 1, substantially as herein described.

14. An assembly for use in making a compacted alloy article according to claim 1 substantially as decribed herein with reference to the accompanying drawings.

15. A compacted alloy article whenever prepared by the method or apparatus according to any one of the preceding claims.

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FIG. 1A

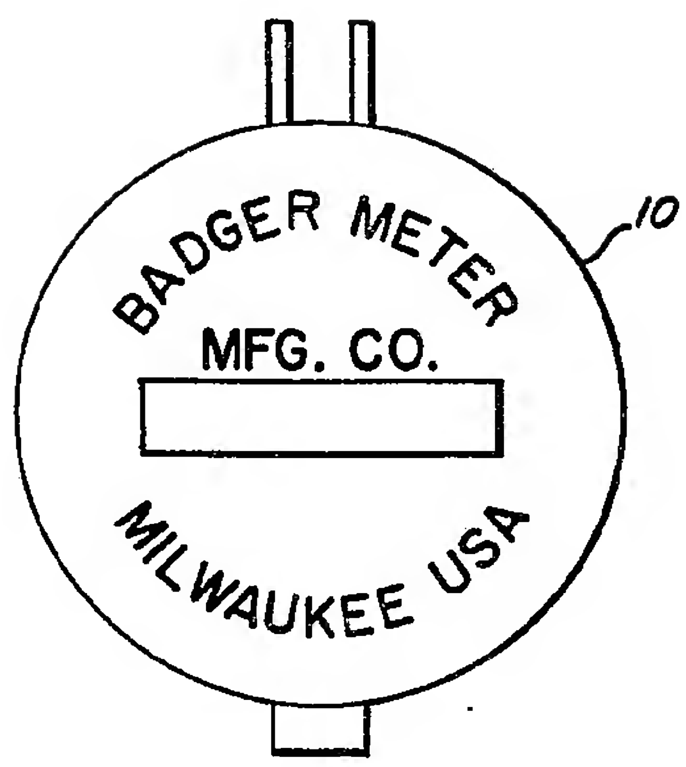

FIG. 1B

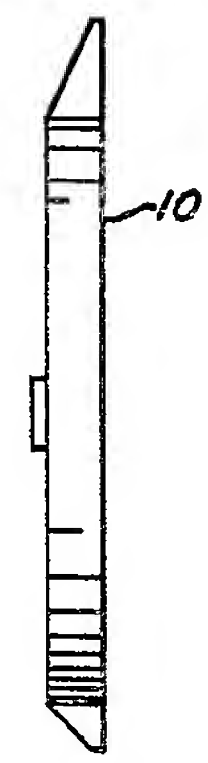

FIG. 3

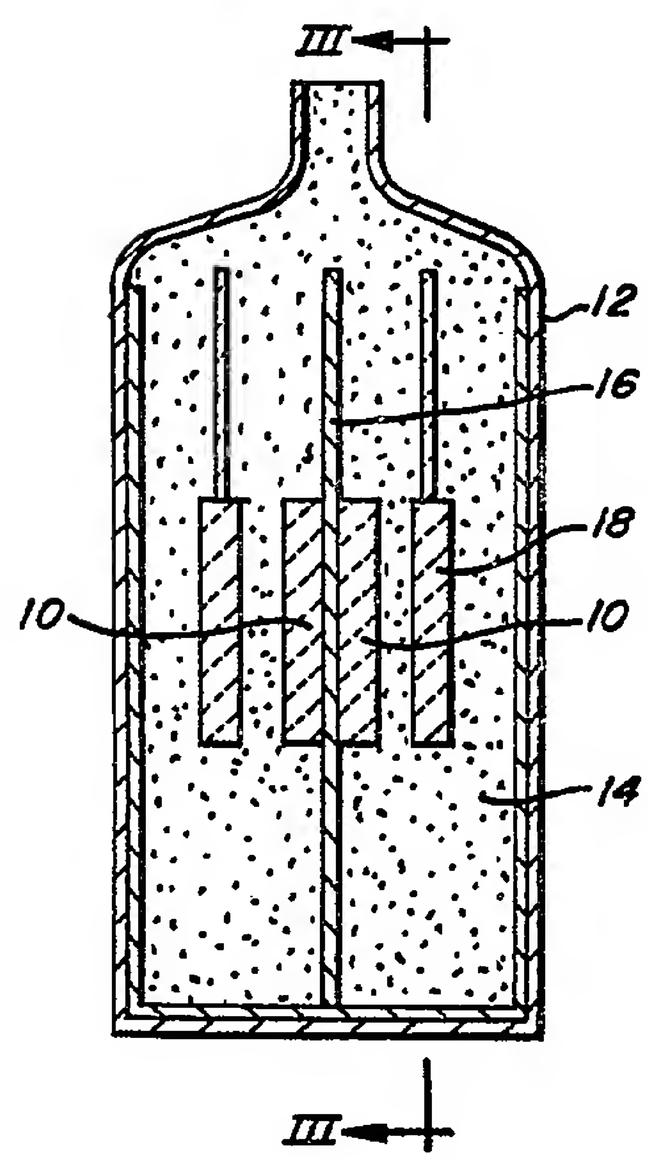

FIG. 2

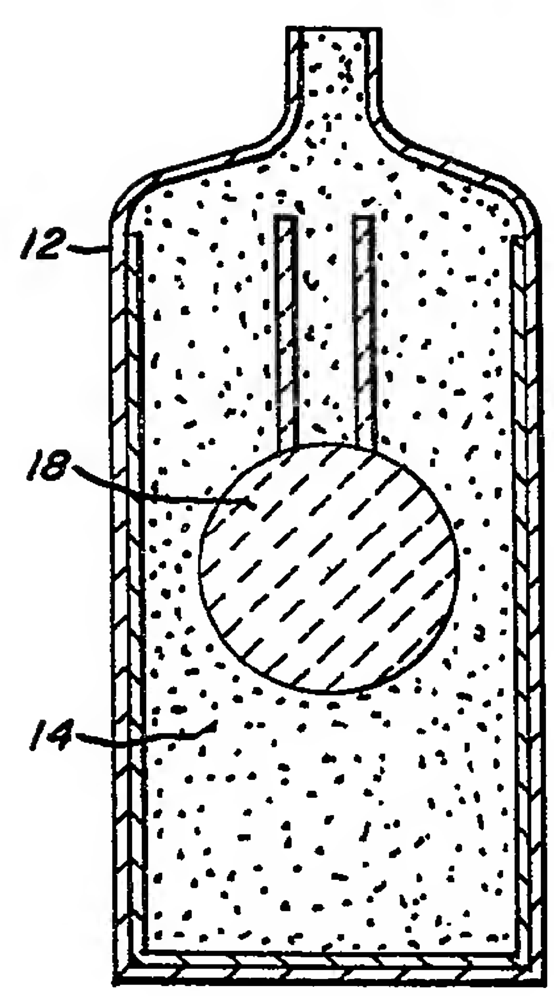

FIG. 4A

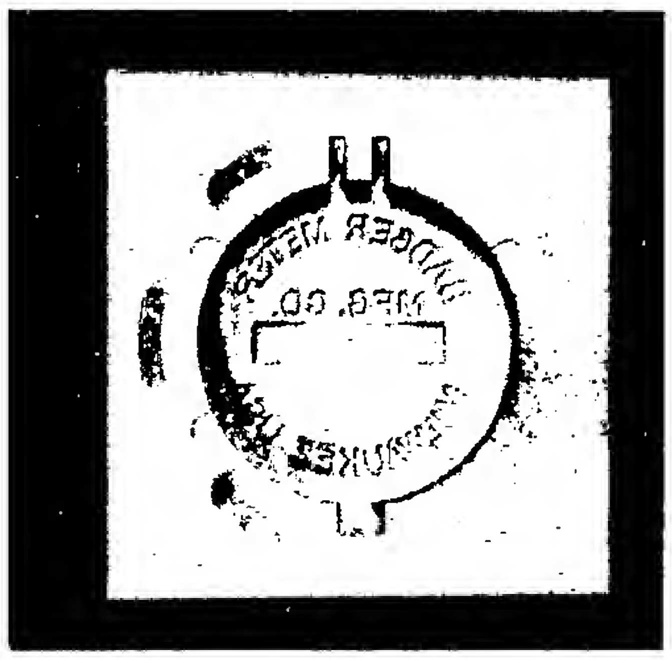

FIG. 4B

FIG. 5